Claims:

What is claimed is:

1. An improved variable optical attenuator (VOA) comprising a VOA package, a movable optical component with a reflecting surface, and a collimator, wherein the collimator is such that the geometry and relative position and orientation of the optical components of which the collimator is comprised are selected to provide minimal wavelength-dependent optical losses.

2. A VOA providing minimal wavelength-dependent optical losses as recited in claim 1, wherein the collimator comprises:

   at least one first waveguide having an end and capable of emitting polychromatic light from this end;

   at least one second waveguide having an end and capable of receiving polychromatic light at this end;

   a housing mounted to the VOA package;

   a ferrule mounted in the housing and having at least one through-hole extending through its length, the ferrule through-hole(s) containing a portion of the first and second waveguides, and the ends of the waveguides and the end of the ferrule all occupying a first plane of the ferrule, this first plane not perpendicular to the central axis of the ferrule;

   at least one lens for collimating and focusing polychromatic light, the lens having a first end and a second end, the first end being planar, and the lens mounted in the housing such that:

   the first end of the lens faces the first plane of the ferrule;

   the second end of the lens faces the reflecting surface of the movable component within the VOA package;

   the plane of the first end of the lens is not parallel to the first plane of the ferrule;

polychromatic light emitted from the end of the first waveguide passes through the lens and is reflected by the movable component back through the lens with at least a portion of the light received by the end of the second waveguide; and

the axial orientation of the plane of the first end of the lens with respect to the ends of the waveguides and end of the ferrule is selected so as to minimize wavelength-dependent optical losses.

3. A VOA as recited in claim 2, wherein the first plane of the ferrule is oriented at an angle with respect to the optical axis of the lens and the first end of the lens is perpendicular to its optical axis.

4. A VOA as recited in claim 2, wherein the ferrule and the lens are such that:

the symmetry planes of both are coincident;

the first plane of the ferrule is perpendicular to the symmetry plane and the angle between the first plane and planes perpendicular to the central axis of the ferrule is θ_1;

the plane of the first end of the lens is perpendicular to the symmetry plane and the angle between the plane of the first end of the lens and planes perpendicular to the optical axis of the lens is also θ_1; and

the first plane of the ferrule and the first end of the lens are not parallel.

5. A VOA as recited in claim 2, wherein the movable optical component tilts about at least one axis.

6. A VOA as recited in claim 2, wherein the movable optical component tilts about at least two axes.

7. A VOA as recited in claim 6, wherein the movable optical component additionally moves translationally in at the axial direction.

8. A VOA as recited in claim 2, wherein the movable optical component is a MEMS structure.

9. A VOA as recited in claim 2, wherein the at least one first and second waveguides are optical fibers.

10. A VOA as recited in claim 9, wherein the first and second waveguides are substantially parallel and close together and occupy a single through-hole in the ferrule.

11. A VOA as recited in claim 9, wherein the first and second waveguides are substantially parallel and close together and occupy distinct through-holes in the ferrule.

12. A VOA as recited in claim 2, wherein the optical axes of the first and second waveguides are in the symmetry plane of the ferrule, this plane defined as the unique plane about which the geometry of the ferrule is symmetric.

13. A VOA as recited in claim 2, wherein the ferrule and waveguides are such that the optical axes of the first and second waveguides are in the unique plane containing the central axis of the ferrule and perpendicular to the symmetry plane of the ferrule, this symmetry plane defined as the unique plane about which the geometry of the ferrule is symmetric.

14. A method for constructing a variable optical attenuator (VOA) which minimizes wavelength-dependent optical losses, the method comprising the following steps:

(1) providing a movable optical component with a reflecting surface;

(2) providing a collimator with an input waveguide, an output waveguide, a ferrule holding a portion of the waveguides, a lens, and a housing, wherein the geometry and relative position and axial orientation of the optical components of which the collimator is comprised has been selected so as to provide minimal wavelength-dependent optical losses;

(3) positioning and aligning the movable optical component and the collimator in a package so that light entering the input waveguide and leaving the collimator is reflected from the movable optical component back through the lens of the collimator in such a way that at least a portion of the reflected light enters the output waveguide with minimal wavelength-dependent losses; and

(4) mounting the movable optical component and the collimator in the package in the aforesaid position and alignment.

15. A method for constructing a VOA which minimizes wavelength-dependent optical losses as recited in claim 14, wherein the collimator geometry is optimized in step (2) by the following steps:

(a) providing a housing;

(b) providing a ferrule which is such that the end of the ferrule and the ends of the waveguides it holds occupy a first plane and the angle of orientation of this first plane with respect to the central axis of the ferrule is $\theta_1 \neq 90$ degrees;

(c) providing a lens having a first end and a second end which is such that the first end of the lens is planar, and the angle of orientation of this end of the lens with respect to the optical axis of the lens is θ_2;

(d) mounting a first component to the housing, the first component being the ferrule or the lens;

(e) placing a second component in the housing, the second component being the ferrule or lens and not the first component, and the placing of this second component such that it is free to rotate about its central axis;

(f) positioning a temporary movable optical component with a reflecting surface such that the reflecting surface faces the second end of the lens, this temporary movable optical component not necessarily being the movable optical component of the VOA;

(g) transmitting polychromatic light into the input waveguide such that the light leaves the end of the input waveguide, passes through and is collimated by the

lens, is reflected by the reflecting surface of the temporary movable optical component back through the lens, is focused by the lens onto the end of the output waveguide so that at least a portion of the light enters the output waveguide;

(h) rotating the second component (see (e)) about the optical axis until an optimal axial orientation is determined, the optimal orientation being an orientation that, in combination with the geometries and relative position of the ferrule and the lens, is such that WDL is minimized; and

(i) mounting the second component to the housing in the optimal axial orientation determined in (h), thereby completing assembly of a WDL-optimized collimator.

16. A method for constructing a VOA as recited in claim 15, wherein the lens is such that its first end is perpendicular to its optical axis.

17. A method for constructing a VOA as recited in claim 15, wherein the ferrule and the lens are such that:

the symmetry planes of both are coincident;

the first plane of the ferrule is perpendicular to the symmetry plane and the angle between the first plane and planes perpendicular to the central axis of the ferrule is θ_1;

the plane of the first end of the lens is perpendicular to the symmetry plane and the angle between the plane of the first end of the lens and planes perpendicular to the optical axis of the lens is also θ_1; and

the first plane of the ferrule and the first end of the lens are not parallel.

18. A method for constructing a VOA as recited in claim 15, wherein the movable optical component tilts about at least one axis.

19. A method for constructing a VOA as recited in claim 15, wherein the movable optical component tilts about at least two axes.

20. A method for constructing a VOA as recited in claim 19, wherein the movable optical component additionally moves translationally in at the axial direction.

21. A method for constructing a VOA as recited in claim 15, wherein the movable optical component is a MEMS structure.

22. A method for constructing a VOA as recited in claim 15, wherein the at least one first and second waveguides are optical fibers.

23. A method for constructing a VOA as recited in claim 22, wherein the first and second waveguides are substantially parallel and close together and occupy a single through-hole in the ferrule.

24. A method for constructing a VOA as recited in claim 22, wherein the first and second waveguides held by the ferrule are substantially parallel and close together and occupy distinct through-holes in the ferrule.

25. A method for constructing a VOA as recited in claim 15, wherein the optical axes of the first and second waveguides are in the symmetry plane of the ferrule, this plane defined as the unique plane about which the geometry of the ferrule is symmetric.

26. A method for constructing a VOA as recited in claim 15, wherein the ferrule and waveguides are such that the optical axes of the first and second waveguides are in the unique plane containing the central axis of the ferrule and perpendicular to the symmetry plane of the ferrule, this symmetry plane defined as the unique plane about which the geometry of the ferrule is symmetric.